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WOOSTER, OHIO, MAY, 1899.

THE HESSIAN FLY.

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Bul. 107

BULLETIN

OF THE

Ohio Agricultural Experiment Station.

NUMBER 107. MAY, 1899.

THE HESSIAN FLY,

Cecidomyia destructor Say.

BY F. M. WEBSTER.

When the writer came to Ohio from Indiana, in 1891, he had just completed an exhaustive series of experiments covering, a period of seven years, relative to the habits of the Hessian fly in the latter State. Bulletin No. 7, Vol. IV, November, 1891, was then issued, prompted by the reasons indicated in the following paragraphs, extracted from the opening pages of that Bulletin.

"There has been much inquiry for information regarding the Hessian fly and its method of work, and, though an old pest of the wheat field, I do not find that it has ever been thoroughly treated in any publication freely and easily accessible to Ohio farmers. I have, therefore, taken up the subject in detail, and hope that this publication will prove useful in the future.

"I wish to continue, here in Ohio, the investigations which I have been conducting in Indiana during the last seven years, with a view of learning the time, throughout the State, when wheat can be sown in the fall, to best escape the attack of the fly, and I hope as soon as practicable to begin a series of experimental sowings throughout Ohio. Therefore, I shall be thankful for any information or assistance which may be afforded me."

While no such systematic experiments, as above mentioned, have been attempted in Ohio, I have always made it a point to secure all possible information in regard to the Hessian fly, with the idea of proving that the species does not materially differ in its times of developing, as between Ohio and Indiana, and that, in the same latitude, recommendations for preventive measures will apply as well in one State as in the

other. Some studies made in Ohio at a later date have been included in Bulletin No. 51, published in 1893, but the supply of both of these bulletins has been exhausted and there is nothing now available, relative to this pest, that can be distributed to such farmers as desire published information with regard to the insect. For this reason I have revised the information contained in these two bulletins, and brought the subject up to date, the present bulletin being, therefore, really a revised second edition of the earlier of the two publications above mentioned.

BRIEF DESCRIPTION OF DIFFERENT STAGES OF THE HESSIAN FLY.

This is a small, dark colored, two winged fly, about one-eighth of an inch long and shaped much like the Wheat Midge, both belonging to the same order and family of insects. The male, Fig. 1, is more slender than

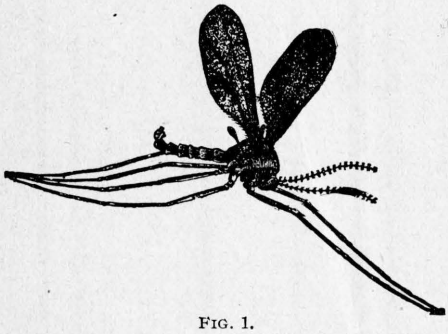

FIG. 1.

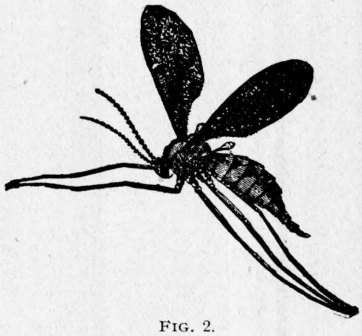

FIG. 2.

the female, Fig. 2, which, when full of eggs, slightly resembles a diminutive mosquito moderately full of blood. The life of the insect in the adult stage is short, the male dying soon after pairing and the female soon after oviposition. The egg, Fig. 3*a*, is about one-fiftieth of an inch long, of a dull reddish color. The larva or maggot, Fig. 4*b*, is, when first hatched, of a nearly white color, with a tinge of red, but later they are very light green, clouded with white. The pupa, Fig. 4*d*, is formed un-

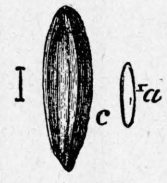

FIG 3.

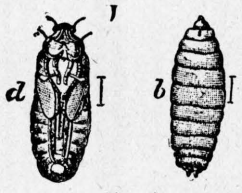

FIG. 4.

der cover of the puparium, Fig. 3*c*, which last is known as the "flaxseed" stage, on account of its resemblance to a flaxseed in form and color. This term is frequently used throughout this bulletin for the reason that the insect is best known under this name, in this stage of development.

EARLY HISTORY.

Although the destructive character of this species had been well known for many years, the adult insect was not described until 1817. The popular term by which it is now universally known appears to have originated, either directly or indirectly, with Col. George Morgan, of Prospect, New Jersey,[1] under the impression that they had been introduced into the country by the Hessian troops on Staten and Long Islands, in August, 1776. In a letter addressed to Sir John Temple, then Consul General for his Britannic Majesty in the United States, dated August 26, 1788, Mr. Morgan said:

> "I have satisfied myself that the Hessian fly was introduced into America by means of straw, made use of in packages or otherwise, landed on Long Island at an early period of the war. Its first appearance was in the neighborhoods of Sir William Howe's debarkation, and at Flatbush[2]."

The correctness of this theory of introduction has always been a matter of contest; but, be it true or not, the first really authentic account we have of the ravages of the pest, in America, was in the immediate vicinity of the locality where the landing of these troops occurred, and in the year 1779 — three years after the event took place. Reports there are of the ravages of insects, said by the unscientific to be identical with the Hessian fly, many years earlier, but these lack authenticity, and when we take into consideration that over a century later at least four-fifths of the reports of the appearances and depredations of the fly are to be accepted only after investigation, we may well exercise caution in accepting similar, early and vague reports. If, however, the pest was introduced at the time and place mentioned, it must have been brought over in great numbers. A little over two years is a short time for even this pest to become seriously destructive over even a limited area, and at least as early as 1780 or 1781 we find farmers in that vicinity adopting a yellow-bearded, Southern variety of wheat, which seemed to be less affected by the attacks of the fly. Its continued advance may be recorded as follows: Pennsylvania, 1786; New Jersey, 1786; Virginia, 1801;* Lower Canada, 1805 to 1816; Maine, 1823; Michigan, 1837; Wisconsin, Indiana and Illinois, 1844; Georgia, 1845 and 1846; Iowa and Minnesota, 1860; South Carolina and

[1] Pennsylvania Mercury, June 8; September 14, 1787.

[2] American Farmer, vol. 7, p. 153.

*This is according to the chronological table given in the Third Report of the U. S. Entomological Commission, pp. 232–3. In the Proceedings of the Agricultural Society of Albemarle (Va.), as published in *The American Farmer*, vol. 1, pp. 300–1, Mr. James Barbour, of Barboursville, Orange Co., Va., states pointedly that the Hessian fly first appeared in that section and "materially affected the crops" in 1798, and he very evidently was familiar with the insect of which he wrote.

Kansas, 1871, and California in 1885.[3] I fail to find any definite record of the earliest appearances of the insect in Ohio. Dr. Chapman states that it ocurred "west of the Allegheny mountains" in 1797, but does not say whether in Ohio or elsewhere. In the Report of the Commissioner of Patents, for the year 1848, p. 535, Mr. James D. Summers, of Troy township, Richland county, makes the statement that be began to apply lime to seed wheat as a remedy for the fly, in the fall of 1840. Its occurrence in 1797, in this State, seems doubtful, but it certainly must have reached here before 1840, the date usually given for its first appearance. In fact, a letter received recently from an aged and very intelligent gentleman, Mr. Luke Smith Motte, of West Milton, Miami county, Ohio, indicates a much earlier occurrence than has been previously recorded. Mr. Motte says:

"My memory runs back very clearly to 1815, and I well remember the plentiful harvest of 1820, when we used the hand sickle, and the reapers put on their overcoats to go out into the fields. The Hessian fly was here long before 1840. The first we remember that farmers' attention was called to this 'fly in the wheat' was in 1824–5, or maybe a year previous. It seemed to spread rapidly, so that farmers became watchful and cautious in regard to time of sowing."

NUMBER AND DEVELOPMENT OF BROODS.

Dr. A. S. Packard states that as a general rule there are two broods of the fly, the first laying their eggs late in April and in May, the second brood of flies ovipositing in August, during September, and a few early in October. On the same page Dr. Packard, under the head: "A third brood may sometimes appear," cites the finding of empty "flaxseeds" in volunteer wheat in Michigan in September, and in a foot-note is the statement that Mr. F. S. Sleeper saw flies ovipositing as late as October 26, and also, in 1878, as early as in February. Mr. Herrick noted the occurrence of flies in October, but supposed them to have evolved from pupæ of the preceding June. Mr. Hulick supposed adults found in Michigan during October to have emerged from pupæ in volunteer wheat. Mr. Caleb S. Fuller, however, reared adults also in Michigan from wheat sown on August 31, and Mr. Tilghman speaks of the appearance of flies in October in Queen Anne's county, Maryland, in a manner that would indicate that it was of ordinary occurrence.

In ordinary seasons, and throughout the area north of Lat. 37° N. and south of Lat. 45°, or thereabout, and between the Rocky and Allegheny mountains, the statement made long ago by Dr. Isaac Chapman that the Hessian fly is double brooded is true. While in the southern portion of Ohio the fall brood of adults appears some weeks later than in the northern part, nevertheless I have found but two destructive

[3] Am. Nat., Vol. XIX, p. 716, 1885.

broods. Between these two broods, however, is a considerable mass of fluctuating individuals, the true position of which is rather uncertain.[4]

There has always been a diversity of opinion as to the number of annual broods of the Hessian fly, even among entomologists, who have decided the question, each upon the data furnished by the area over which he has himself studied the insect, while as a matter of fact, if all of the work accomplished is brought together and studied in connection with the somewhat variable habits of the insect, as affected by geographical distribution, we shall find, not that the work of the entomologist has not been well done, but that what is true in one locality may not necessarily hold good in all others, and that a view of the whole area of distribution is likely to show that all have been right, except in their general conclusions. I believe it is due to this that entomologists have claimed anywhere from two to six annual broods of the Hessian fly, while it seems to me doubtful if there are as many as six in the far south, while on the northern border of its habitat there may be but one.

The idea of these additional broods is a very old one, and dates back to 1820, Mr. James Worth having that year observed the adult April 19; eggs, April 24; pupæ, May 15; adults early in June, and on the 12th of same month all stages were observed. Adults were noticed from the 15th of the following August until October, and again November 25, and he reared them indoors, December 25 and February 20. In summing up the matter he says: "It may then be said, that during the past year, (1820) there have been three complete broods and partially a fourth." [*American Farmer, Vol. III, p.* 188, *also loc. cit., p.* 213.

As Dr. Lindemann, of Moscow, Russia, in his "Die Hessenfliege in Russland," has well stated, the puparia are greatly influenced by environment, temperature, etc., and this is probably true of the other stages, larvæ of different ages being, for all we know, influenced to a different degree. To these facts must be added another of considerable moment, viz., while nominally two brooded, "flaxseeds" collected by me in the spring of one year have lived over to the spring of the following year. This is also true of at least one of the parasites of the species. How far the number of these interlopers is augmented by a retarded development of greater or less extent it is impossible to say, but that there is an accession through this means there can be no doubt. In fact, it would appear as though nature had in this way provided against the extinction of the species.

It would seem that we had here the two perplexing features of the problem of the number of annual broods, viz., variation in time of appear-

[4] Dr. Fitch states that the eggs of the fall brood are deposited in the State of New York early in September, and also that "the deposit is doubtless made later to the south of us than it is here in New York." (Seventh Report.) Mr. Edward Tilghman observed oviposition in Queen Anne's County, Maryland, about latitude 39° to 39° 30′, during the second week in October, and mentions it as of usual occurrence. (The Cultivator, May, 1841.)

ance of the brood, due to latitude; retardation of individuals due to any one of several influences; and, possibly, acceleration in the case of others. As applicable to the country lying between the Allegheny Mountains and the Mississippi River, and between the Ohio River and the Great Lakes, I have attempted to illustrate in Fig. 5, ideographically, the annual cycle of this insect, which can of course be only approximately correct for any single locality, there being a variation of nearly if not quite one month in the season of development between northern and southern Ohio. It will be observed that there are four seasons in this cycle, two of activity and two of inactivity, or, we might term the latter resting seasons. Over this area the winter resting season is by far the longer, while the two active seasons are about equal. Toward the south I believe the winter season will be found to be shorter and the summer season lengthened until they become equal, while to the north I confidently look for the autumn season of activity to wholly disappear and the species found to be single brooded.

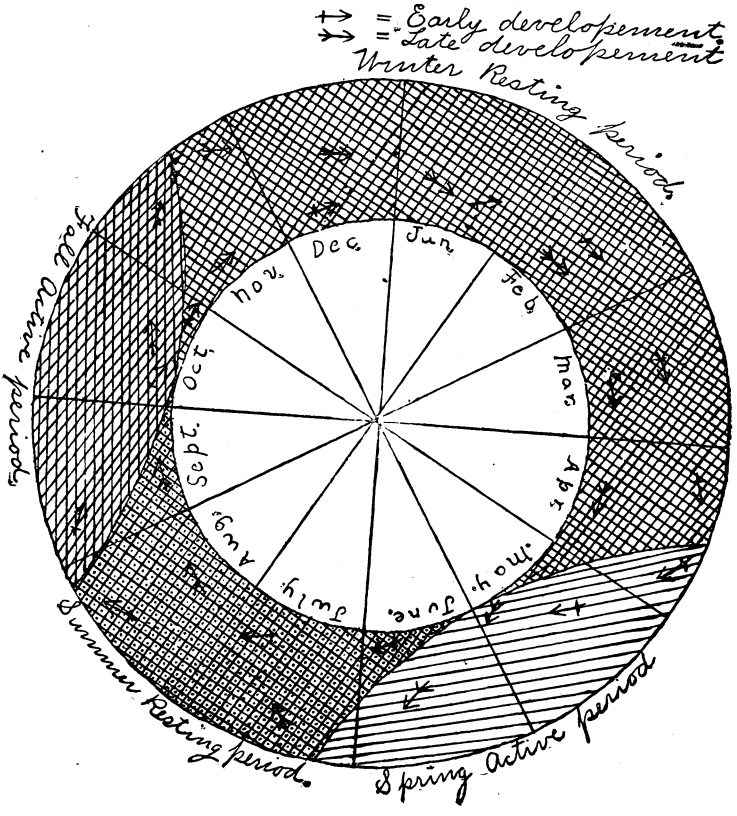

Fig. 5. Illustrating the annual cycle of the Hessian fly.

It will be noticed that the arrows alternate from the outer to the inner edges of the circle thus: The arrow indicating the late development of larvæ in November, crosses to the inner edge at May, indicating that the adults from these will appear late the following spring; while larvæ entering flaxseed stage in October develop adults early the following spring — the arrows in this case crossing from the inner to the outer edge of the circle.

Heretofore we have told people that the fly could not exist except where fall wheat was grown. But this can be said no longer, as the pest occurs in North Dakota and in a locality where fall wheat is never sown. Since the fall brood of flies emerges continually earlier as we go northward, it seems to me that we must eventually reach a point where it will cease to appear in autumn at all, and will go over until spring, a state of affairs that will easily account for the breeding in spring wheat in North Dakota. In other words, I expect to find that nature has protected the species alike from the protracted northern winter, and the equally prolonged southern summer, by varying its resting season with the latitude, and, possibly, also with its proximity to the sea coast. That is, we shall find the insect passing both the hot and cold seasons largely in the flaxseed stage, that being the stage of development during which it is best protected from the elements and lack of food.

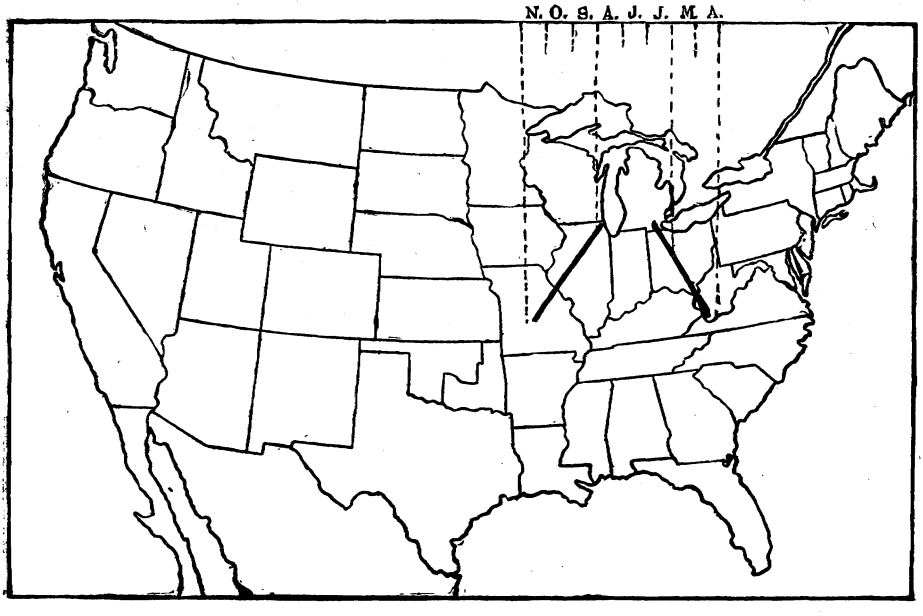

Fig. 6. Illustrating the divergence of the two annual broods of the Hessian fly with reference to date and latitude; the letters at upper margin, N, O, S, J, J, M, A, indicate the months from April to November while the heavy, oblique lines represent the diverging of the two broods to the southward and their approach to each other northward.

There are several good reasons why we might expect the fall brood to become extinct to the north, while the spring brood continues, the principal one being that there is not sufficient time for the former to develop before the cold season begins. Besides, in the continuity of the species it can best be spared, and I understand it is not present in England. In nearly all cases where a species is two-brooded, the spring-appearing brood of adults is the producing, while the fall is the diffusing brood. The spring-appearing flies are loth to leave the field in which they originated, and prefer to oviposit on the tillers of the wheat plant, while the autumn-appearing adults will spread out everywhere over the country, and will seemingly, scent out a field of wheat at long distances. They can even be drawn to very small plots in the midst of large cities.

It would seem, then, that the continuity of breeding having been interfered with by the winter months, we might naturally expect some of the adults that should appear in the spring, to emerge in the fall in sufficient time for their offspring to become far enough advanced to enable them to withstand the winter, yet lacking so much of full development that a considerable period of time in spring would be required to enable them to become fully developed. It would not be at all surprising if we found these stragglers appearing simultaneously with the advanced individuals, if such there be, of the next fall brood. I think that we can accredit the apparent additional broods to this overlapping. I have tried to make this clear in Figure 6. Now in regard to the time of the appearance of the real brood, the observations of thirteen years in Indiana and Ohio have shown that, in the spring, the Hessian fly develops later as we go northward, simultaneously with the advance of the season, which is estimated to be, approximately, 12 miles per day; so that the spring brood of flies which might occur in Virginia and southern Kentucky, in April, would probably not put in appearance in Ontario, Canada, Michigan and Wisconsin until June. The same extended studies over precisely the same area has shown that in the fall brood this condition is reversed, and that the adults emerge earlier in the north and later as we go southward in about the same proportion. In Figure 6 I have assumed that Hessian flies were abroad in Virginia and southern Kentucky during the latter part of April. I have assumed this to occur because, though I have not studied them there, I have studied them in southern Indiana, where this state of affairs does exist. Throughout Indiana and Ohio I have traced the development of these broods northward to the Michigan line, and shown that there is a much shorter period between the spring and fall brood in northern Ohio and Indiana than there is in the southern portion. In the fall this amounts to nearly or quite an entire month, as is indicated in Figure 7.

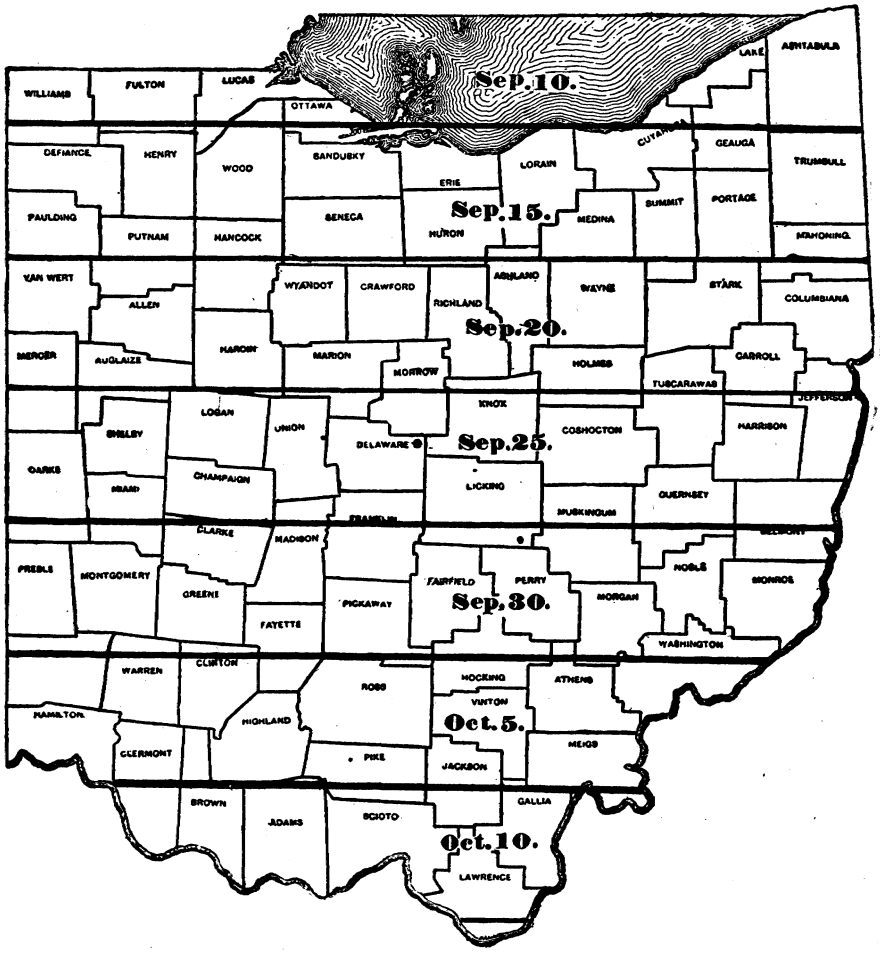

Fig. 7. Map showing areas over which the adult Hessian flies, of the fall brood, have developed and disappeared by the dates indicated between the lines.

Referring to Figure 6, then, it will be seen that at a point somewhere near central Michigan, Ontario, Canada, Wisconsin and southern Minnesota, two heavy oblique lines would come in contact with each other. By this I have indicated that with a continual late appearance of the fall brood and a continual early appearance of the spring brood there would come a point where it would be impossible for the insects of the first brood to reach the adult stage in time for the progeny of these to become sufficiently advanced to stand the winter and they would therefore go over until the following spring in a stage where they could pass the colder months safely but the effect of this would be that the fall brood of larvæ would drop out and the species become single brooded. As near as I can determine without actual studies and investigations, this point

would be somewhere in the vicinity of latitude 45° north, and in that latitude I should certainly expect to find the Hessian fly single brooded, instead of double brooded, which would easily admit of its attacking spring wheat, as, with the exception of one observation by Dr. Fletcher, we have no record of its developing on any of the grasses in North America.

As to the number of broods south of extreme southern Indiana and Illinois, I have never been able to study the species in that latitude, but it seems to me that it would not be possible for more than a certain number of broods to develop upon the grain plant, of which there is but one crop grown annually. Still it is not impossible that an additional generation may develop in volunteer plants, although it would hardly seem that this could follow to any marked degree. What is really needed is a careful study of the Hessian fly from the latitude of extreme southern Illinois southward to the Gulf; and I do not believe that it is possible to give an accurate knowledge of the life history of the insect until this has been done. As I have indicated, the situation in England does not differ materially from what I have stated as true in the northern portion of this country, as there does not seem to be more than one annual brood there. Whether the same may be said of Russia or not, I would not care to say, as Dr. Lindemann appears to have made a most careful study of the species in his country; but I have always thought he may have fallen into precisely the same error that we have in this country.

EXPERIMENTS AND OBSERVATIONS MADE IN INDIANA.

My own experiments, notes, and observations upon this insect in Indiana extend over a period of a little over six years, and while during that time the Hessian fly received little more attention than was given several other wheat-destroying species, a considerable number of facts accumulated which, while not by any means clearing up all of the mysteries of the pest, nevertheless serve to throw some light on several obscure points. Unless otherwise stated, all of my observations and experiments herein recorded were carried on in the adjoining state of Indiana, extending from latitude 37° 50′ to about 41° 45′ N.; and with the exception of meteorological conditions as indicated by what are known as Isothermal lines, the results will, I still think after seven years additional study, apply equally as well in Ohio as in Indiana.

These experiments and observations were conducted almost exclusively out of doors and very largely in the fields, as I consider indoor and breeding-cage observations on this species, except for the purpose of securing specimens and parasites, of very doubtful value from an economic standpoint or as indicating its normal habits. The observations have many of them been once and often twice substantiated.

At LaFayette, Ind., latitude 40°·27′, (Columbus, Ohio, is latitude 40° N.) wheat plants were transferred from the fields to breeding cages April 5, 1890, and kept out of doors. The seed producing these plants had been sown September 3. On April 17 a female emerged, and a male appearing soon after, these, on April 22, were both placed together on young growing wheat, planted in a breeding cage out of doors. From these, adults were secured June 8. The attempt was made to follow the offspring of these, but failed on account of the wheat being killed by rust. On June 7, and also on the 14th, 1888, in the same locality, adults were observed ovipositing, the eggs being placed on the youngest and most tender shoots, and there was every evidence that these eggs developed through the larval to the "flaxseed" stage by early July. Besides, I have observed in the same locality late-growing shoots literally overrun with very young larvæ on the 26th of June, and found larvæ as late as the 10th of July.[5]

On October 16, 1887, Mr. W. S. Ratliff, who made a great number of experiments for me, near Richmond, Ind., (latitude 39° 51′, and about the same as Springfield, Ohio,) secured adults from a small plot of wheat plants which appeared above the ground September 4. From a plant from this same plat that had been transplanted in doors, he secured an adult female 11 days earlier. In either of these cases, with favorable weather, the female could have sent her offspring into the winter in the "flaxseed" state. Mr. Ratliff also observed adults on July 10, 1887. At LaFayette, Ind., the same autumn, I saw females ovipositing on November 3, in a temperature of 64° F., among the plants. From a plat sown August 13, and which came up on the 17th, I obtained adults of both sexes on October 1, 44 days after the plants appeared and 48 days after sowing. That larvæ, even though quite immature when winter begins, may survive till spring, has been demonstrated again and again, and was especially true of the exceedingly mild winter of 1889-'90. In fact, by a series of sowings all stages of the insect can be produced in small numbers continually from April to October, and by keeping a cage indoors I have produced adults in abundance in January.

It is true that observations during a single season, in a single locality, might produce apparently good evidence of a third brood, but a continued close study of the species in such locality will probably show it unfounded. That these aberrant individuals may, under favorable conditions, collect or "bunch" together in certain fields is probably true, but my own experience has been that the following year this irregularity will have disappeared or have been reduced to a minimum by the effect of the weather during midsummer and winter. On June 24, 1887, near Princeton, Indiana, latitude 38° 23′ N., I found a field of wheat, sown

[5] Flies began to appear on the farm of Mr. Jonathan N. Havens, Shelter, Island tp., Suffolk County, Long Island, on the 16th of April, 1787. (American Farmer, Vol. VII, p. 153.)

about the first of the preceding November, literally alive with larvæ from one-fourth to nearly or quite full grown. There were no pupæ to speak of in this field at the time, but in other fields in the vicinity these were abundant, but here there were no larvæ to be found. At this date wheat harvest was at its height. The late-sown field had evidently attracted the late-appearing adults of the fall before, and their progeny, living over in this field, as delayed larvæ, emerged correspondingly late in the spring, giving rise to the generation of larvæ observed by me. My reason for taking this view is that I have several times tried to draw off the spring brood of flies by offering them young plants on which to oviposit, but have always failed, as they seemed to prefer tender shoots of older plants to the young plants themselves. In the fall this characteristic seems to be somewhat the reverse, although even then, if attacked after tillering, the tillers will be chosen instead of the main stem. The fall brood of adults is probably the migratory brood, and their power of detecting wheat plants is almost phenomenal.

I have drawn them to a small plat of wheat sown in a secluded corner of my garden, in the midst of town, fully half a mile from any wheat fields. But, be this as it may, a second brood of larvæ in June would be rather difficult to sustain, as the puparia of the earlier part of the month are known to remain in that stage until September. Neither have I been able to secure any better evidence of a brood originating in volunteer wheat during July and August. Puparia are to be found every year from one end of the state to the other in this volunteer wheat, but in Indiana I have never found these sufficiently numerous to imply a distinct brood. Professor Forbes and his assistants, working in Illinois, appear to have a greater confidence in this extra brood than myself, although, as will appear further on, our experiments were carried on the one perfectly independent of the other, though only a few miles apart.

My attention had been called to the condition of this field near Princeton, by Hon. Samuel Hargrove, a member of the State Board of Agriculture, who willingly agreed to further aid in the investigations by sowing for me plats of wheat at intervals of about two weeks, beginning as soon as possible after harvest. Being detained in Lousiana myself until nearly the 1st of August and the weather being exceedingly dry, no plats were sown until August 4, 1887, followed by another on August 22, and a third September 5. These were sown on one of Mr. Hargrove's farms, about 10 miles northeast of Princeton, about the latitude of Lawrence county, Ohio.

The first two sowings, owing to the drouth, came up sparingly and about the same time. The third was also affected by drouth, and did not come up until about the 1st of October. These plats were sown along the lower edge of a high, rolling stubble field, which had been too dry to plow, and in which I had found an abundance of "flaxseeds" the preceding June.

These plats were examined by me on October 8. The two earlier-sown had thrown up a good growth of plants, which had tillered finely, being along a low ravine. On these plats I found a number of larvæ, which were nearly or quite grown, and a less number of "flaxseeds," one of which was empty. Besides these, the plants were literally alive with very young larvæ, so young in fact, that they had not yet lost their reddish tint. The third plat had sent up the normal number of plants, which were now in the second leaf. These plants had not appeared in time for the earlier deposited eggs, but were even more seriously infested by young larvæ, than the plants of the two earlier plats. One of the plants from the last plat contained twenty-six young larvæ, all of which must have hatched from the eggs only a few days prior to my observations. Now, from whence did the progenitors of these young larvæ originate? Most assuredly not from volunteer wheat, because there was none. Not from my earlier-sown plats, else these would have shown the effect. There are, it seems to me, but two other sources from which they could have come, viz., the stubble, which I know to have been infested, and grasses, which we have no knowledge of the species affecting this side of the Rocky mountains.

These plats were plowed up soon after examination, as I was afraid to allow them to stand thus, a menace to the adjoining fields the following spring, though the plants would have probably been destroyed before even a small portion of the larvæ matured.

From all the information that I am able to gather, the usual time of appearance of the fall brood of adult flies in southern Indiana is the last portion of September, and first days of October. This is, I believe, the opinion of the most observing farmers, including the late Hon. J. Q. A. Seig, of Corydon, Harrison county, who was also a member of the State Board of Agriculture and as familiar with the earlier stages of the pest and its effect upon fall wheat as I am myself. Mr. J. P. Louden, of Sharp's Mills, same county, stated that wheat sown on October 1, 1886, was damaged 50 per cent., while that sown on the 6th was injured only 15 per cent. Mr. J. A. Burton, writing from Mitchell, Lawrence county, November 24, 1887, gave the results of his examination of wheat fields as follows: Fields sown September 8, about one plant in 8 infested; sown September 15, about one plant in 12; sown September 22, about one plant in 50, and sown October 1, seemingly free from injury. The observations of these gentlemen also coincide with my own, made in November, 1888, in Harrison and Posey counties. Therefore, from all the information which I have been able to gain, the best season for wheat sowing, to avoid the attacks of the Hessian fly in extreme southern Indiana, is soon after the 1st of October. Exactly how far northward this advice will apply I am unable to say, but am inclined to think it would cover territory lying between latitude 38° and 39°, and possibly 39° 30′, although near the northern limit

it would probably be safe during ordinary years to sow soon after September 25.

During the years 1887 and 1888 Mr. W. S. Ratliff made a large number of very careful observations, and sowed a series of plats of wheat on different dates near Richmond, Ind. In 1887 plats were sown August 5 and 29, September 12 and 26. All of these plats were attacked and more or less injured except the last, which as late as December 19 showed not the least injury by the Hessian fly. Up to May 31, 1888, there was very little injury to this plat, and even on the above date there were very few larvæ as compared with the number on the others. From this date on till July 11 the plats were all injured by black and red rusts, chinch bugs, and the wheat stem maggot, the greater injury appearing to fall upon this, so that at harvest, July 11, the last was the poorest of all in yield, that sown August 15 being the best. The sowings of 1888 were as follows: September 6, 20; October 4, 22; November 1. On November 14 the first plat was found to be infested by larvæ of the Hessian fly. During June, 1889, chinch bugs again attacked the plants growing on these plats, and the grain aphis seriously injured the later sown plats, so that at harvest July 5, these latter were the poorest of all, the other three averaging about alike. All of these plats during both years had been sown in narrow strips among corn along one side, the remainder of the field being corn, and later also sown to wheat, thus bringing the latest-sown plats between those sown earliest and the entire field itself, as appeared to me, making the severest test to which I could subject the several plats. The results, while not conclusive or even entirely satisfactory, indicate that in that latitude about September 25 is, generally speaking, a good time to sow wheat to escape fall attacks of the fly and winter killing. A series of plats sown for me by Mr. Miles Martin, of Marshall, Parke county, Ind., is very near the same latitude as Richmond, but nearer the western border of the State, gave rather more conclusive results, the sowings of September 22 being almost entirely exempt from the attack of the Hessian fly, while earlier plats were infested.

In regard to my own observations at the Experiment Station at Lafayette, Indiana, I may state that I was never able to provoke a disastrous attack of the pest, though there was nothing left undone which could possibly induce the adult flies to oviposit at any time between March and December; and there is probably not a month between these dates during which the insect could not have been found in all of its stages. The two destructive broods, however, invariably appeared in the fields in May and September; in the latter case usually before the 20th.

My own experimental sowings were rather more elaborate and extensive than those of any of my correspondents, comprising a number of varieties and extending over several months. Without going into details, the experiments and results may be summarized as follows: 1887, plats comprising the varieties Michigan Amber, Clawson and Velvet

Chaff, each, one width of a grain drill and twenty rods in length, were sown on the following dates: August 13, 27; September 10, 24; October 8, 27; November 5, 19. The autumn was very dry, and the plants of the first six plats went into winter in poor condition, being very small, while the last two sowings did not come up until the following spring. The severe winter destroyed the plants so generally, that only the first three produced sufficient grain to pay for harvesting. These were also the only ones to suffer from the fall attack of the fly, the first producing adults October 1. Plat 8, was attacked on the following June, and on the 26th was badly infested with young larvæ, full grown larvæ and puparia, the latter, the most numerous, were found on the 16th of July. The plats harvested produced a poor crop, but the Michigan Amber ranked first, Velvet Chaff second, and Clawson the poorest of all.

The condition of the Hessian fly in these three plats, at the time of harvest, July 10, 1888, may be inferred from the result of examinations made on this date:

Empty "flaxseeds"	15
Containing healthy pupæ or parasites	69
Larvæ	16
Total	100

August 3, the state of the insect in these same plats was as follows:

Empty "flaxseeds"	53
Containing healthy pupæ and parasites	47
Total	100

The condition of the insect on September 1, as shown by examination of the stubble, is indicated below:

Empty "flaxseeds"	55
Healthy "flaxseeds"	28
Parasitized "flaxseeds"	17
Total	100

Notwithstanding the per cent. of healthy puparia passing the summer was small, there is little probability that many adult flies emerged. A plat of the same dimensions was sown July 16, along one side of the first three sown the previous fall, the plants of this last sowing coming up ten days later. This plat was closely watched. After July 17 only an occasional larva was found on volunteer wheat and none of course on the latest sown plat. By August 4, plants had been destroyed by the combined influences of chinch bugs and dry weather, but a second plat had been sown adjoining, and the plants of this appeared above ground on August 6. On September 4, 200 plants were examined and but two larvæ

were found thereon. A second examination of the same number of plants from this plat, on September 15, revealed a small number of young larvæ. A third examination of this plat on October 6 showed about 1 per cent. of the plants to be infested. Stubble from the three original plats, kept in breeding cages, out of doors, did not give adults until the 17th of September, although it is quite probable that some few were abroad before that date. It will be seen, however, that no great number could have emerged from the stubble, and the increase in the number of empty "flaxseeds" between July 10 and September 1 is doubtless to be attributed to the development of parasites. This appears all the more probable, as I have repeatedly observed these parasites during July and August emerge in breeding cages, and at once begin to oviposit in "flaxseed" in the stubble from which they had themselves emerged.. The percentage of healthy puparia reaching September in safety, however, was probably unusually small, as experiments on the same ground the following year did not suffer near so much from either fall or spring attacks. Another feature of these experiments is, that it strongly indicates that the larger per cent. of the parasites emerge prior to the 1st of August. Indeed, stubble from the entire length of the State, collected in June and placed in breeding out of doors at LaFayette, has indicated the truth of this.

The sowings of 1888 were made on August 30, September 18, October 3, 6. Of these, only the first sown were attacked in the fall, that sown on September 18 being in the best condition the following July. During May, 1889, the plants of these plats were found to be much less infested than some fields a cosiderable distance away, although such fields had been sown on oats stubble, while the ground on which my experiments were located was the same that had been used for this purpose the previous year.

The sowings of 1889 were continued on the same grounds, the plats being sown September 3-20, October 4-18, November 4. The autumn attack was the most severe on the first plat, but the extremely mild fall and winter was so favorable to the development of the flies that the spring attack was unusually severe, and appeared to fall upon the three earlier sown plats with about equal force. The later sown plats, though the plants were much the younger, did not suffer so much, but these were very seriously affected by the weather during early spring.

These experiments appeared to indicate that, in this latitude, while wheat sown as early as the last of August may under favorable conditions and during particular seasons produce as good or even a better crop than when sown at a later date, yet such cases are the exception and not the rule; but that wheat sown as soon as possible after the 20th of September stands the best chance of evading the attacks of the fly and withstanding the unfavorable weather, the regular operations of the University farm during the last seven years certainly substantiate. It is the custom with the experiment farm, each year, to sow the regular field crop at this time,

and in no case has severe injury been sustained from attacks of the Hessian fly. Fields on adjoining farms sown at earlier dates have frequently been seriously injured, although this has not invariably followed.

Another series of experimental sowings was carried on for me by Hon. W. A. Banks, near La Porte, Ind., about latitude 41° 35′. The first series of these sowings was begun in August of 1887. The sowings of 1888 were not carried on under Mr. Banks' immediate supervision, and were of little value. No experiments were made in 1889, but a well planned and carefully executed series were sown in the fall of 1890. The series of 1887, each of which comprised two widths of a grain drill, extending along one side of the field about 60 rods in length, the first of which was sown on August 13, the plants appearing above ground within a few days. The second sowing was on August 23, a third on September 2, the fourth September 12, the fifth September 22, the sixth and last on October 7. These plats were visited by me on October 14, and their condition found to be as follows: The first was found to be infested by great numbers of larvæ and puparia, some of the shells of the latter being empty, and the plants were seriously damaged. The second plat was even worse injured than the first, and the third much worse than either of the others. The fourth appeared to be almost as badly infested as the third, but it had only partly tillered, and hence there was a better prospect for it to throw up unaffected shoots. The fifth had not tillered, and was only very slightly infested, with very young larvæ, while the sixth was not yet up.

On April 12, 1888, the plats were visited again. About 25 per cent. of the plants on the first three plats appeared to have survived. The fourth was apparently 50 per cent. better, the fifth was in almost as good shape as the fourth, while the sixth was backward, the plants being small and thin on the ground.

The estimate yield, made by Mr. Banks at the time of harvest, on the basis of 20 bushels per acre as an average yield, was as follows: First plat, 50 per cent.; second, 50 per cent.; third, 65 per cent.; fourth, 90 per cent.; fifth, 70 per cent. The remainder of the field was sown on September 2, and shared in the destruction in common with plat 3. Another field at some distance from this was sown about September 20 and sustained no material injury.

It will be observed that the first three plats were sown almost at the same time as the first three at LaFayette, yet stubble from the first three plats at La Porte, collected on September 2 and placed in a breeding cage beside another containing stubble from the first three at LaFayette, gave adult flies nearly a week earlier. In other words, the majority of the adults from Mr. Banks' plats emerged prior to September 15, while those from my own did not reach their maximum numbers until after the 15th, and from then on till the 25th. In both cases, however, a few stragglers emerged occasionally until early in October. As previously stated, the

plats of 1888 were not properly sown, Mr. Banks not being able to attend to them himself; but a visit to the locality on November 8 revealed but very little injury to wheat which had been sown after the middle of September.

The experiment plats of 1890 were sown September 1, 10, 20, 30. These were examined late in October and fully substantiated the experiments of previous years. The sowing of September 1 was considerably injured, while that of the 10th was very seriously affected, as was also a large field adjoining sown but a day or two later. The sowing of September 20 was comparatively free from attack, while that sown September 30 appeared to have almost entirely escaped injury.

The sixth and last series of experiments were made for me by Hon. J. N. Latta, at Haw Patch, Lagrange county, in about the same latitude as La Porte. The sowings were made in 1887, the first being drilled on July 28, but owing to drouth the plants did not appear above ground until about the 28th of August. The second plat was sown on August 15, but came up the same time as the first; the third, sown Septmeber 1, came up September 6; the fourth, sown September 12, came up September 21; the fifth, sown September 24, came up the 28th; while the sixth and last was sown October 12, and did not come up until about the 20th. These plats were examined by me on October 17; the first three and the last sown were very poor, the fourth and fifth promising a fair yield. A field adjoining, sown on the same day as plat 5, did not suffer from the fly and produced nearly an average yield of 20 bushels per acre. The results of these meager experiments have, as a rule, proven correct in the fields of the farmers. I have not only observed this myself, but it has become well known in the locality that wheat sown before September 15 and after the 30th of the same month seldom produces a good crop, while that sown between the 15th and the 25th is the most likely to escape the attack of the Hessian fly, and, as a general thing, winters as well as that sown earlier, provided the sowing has been done properly.

STUDIES AND OBSERVATIONS IN OHIO.

No systematic field experiments among farmers have been carried out in Ohio, as was done in Indiana, but examinations have been made in wheat fields throughout the State, whenever opportunity was offered to do so, and these have extended from the extreme northern to the extreme southern portions, and during nearly all seasons of the year.

Besides these field observations, the Experiment Station has carried out an almost continuous series of early and late sowings for the last eleven years, beginning in 1888, at Columbus, and with the exception of a single year, extending over a period of four years. At Wooster, the series was started in 1893, and with the exception of two years, extended continuously up to 1899. These sowings were carried on under the

direction of the Agriculturist of the Station, Mr. J. F. Hickman, and though the principal object of the experiment had no special reference to the Hessian fly, yet it will be seen that the sowings were an exact continuation of those that I had been carrying on in Indiana. Without going into details, then, it will be sufficient to state that at Columbus, Ohio, latitude 40°, it was found that the fall brood of the Hessian fly had largely appeared and disappeared by the 25th of September; and that fall wheat sown after that time, was almost wholly exempt from the attack of the larvæ. At Wooster, latitude 40° 49′, the experimental sowings have shown us, very clearly, that the fall brood of flies have disappeared by the 20th of September, and I believe, usually, by the 18th; although in some seasons wheat sown as late as the 14th of September has suffered quite severely from attack of the fall brood of larvæ. As compared with the similar latitudes in Indiana, it will be seen that these results are almost exactly parallel with those obtained in the latter State, and based as it is upon these data, secured in two states during the thirteen years that I have been making the Hessian fly a study, the map shown in Fig. 7, will give an approximate idea of the season during which the fall brood of flies are abroad throughout the State. It is not to be supposed that these dates apply exactly over the whole area between the heavy lines on the map; as, for instance, there would, as a matter of course, be a few days difference between northern Wood county and southern Seneca county; or between northern Wayne county and southern Carroll county; or between northern Logan county and southern Champaign county; but the dates given are as near as can be obtained without actual experimentation upon the farms located within these various areas. For the sake of convenience, these cross lines on the map in Fig. 7 are located upon the degrees and half degrees of latitude, as these will always furnish a basis from which it will be possible for the exact farmer to work. Of course there is always the uncertainty to be taken into consideration that with a rather high temperature and moist ground, wheat will germinate much more quickly than if the weather happens to be very dry; so that, in order to be safe the farmer will need to delay for perhaps two or three days later than the dates given throughout the southern border of the area within which he may reside, while the one located near the northern border will probably not have occasion to take this precaution.

OVIPOSITION.

The habits and transformations of the Hessian fly in America seem to have been first thoroughly studied by Dr. Isaac Chapman, who gave us substantially the life history, as it is now understood, in a paper published in 1797.[6] In 1841 there appeared three important contributions to the

[6] Memoirs of the Philadelphia Society for the Promotion of Agriculture, vol. V.

literature of the species, viz.: A Brief Account of the Hessian Fly and its Parasites, by Edward C. Herrick[7]; the second by T. W. Harris[8], and the third by Mr. Edward Tilghman[9], who had also written on the subject substantially the same 21 years before.

Mr. Herrick described the egg, and both he and Mr. Tilghman observed and recorded the method and place of oviposition, both stating that the eggs were placed on the upper sides of the leaves in the long creases or furrows thereon. Prof. Riley, however, records[10] the fact that this is not always the case, but that the spring brood of flies at least sometimes push their eggs under the sheath and between it and the straw. As to the number of eggs placed at one time, Mr. James Worth stated that he had counted 208 eggs on a single leaf.[11] Mr. Herrick says that the number varies from one to thirty. Prof. Riley says the eggs are placed in irregular rows, ordinarily of five or ten in each row. Prof. A. J. Cook, however, states that the female rarely deposits more than three eggs without changing her position, and generally but one.[12] He does not definitely state that no more are deposited on each leaf, but states that "in case she lays but one it takes less than a quarter of a minute and less than half a minute to lay three, when they are all laid without a change of position on the part of the fly. After laying she seems to draw in her ovipositor, soon to extend it again, at the same time crowding into it the one, two or three eggs that are next to be laid. She then flies to another leaf, alighting usually, not always, with her head toward the end of the leaf."

The eggs are deposited by the female very soon after she hatches from the "flaxseed," on the upper side of the leaf, as a rule, as indicated in Fig. 8. This task is finished in a few days, after which she dies. The

FIG. 8.

young hatching from the egg works its way downward, beneath the sheath to its base. In the fall this is just above the roots below the ground, as shown in Fig. 9, but in spring they do not go below ground, as a rule, but stop at or near one of the lower joints. The effect of the maggots on the young plants in the fall is fully illustrated in Fig. 9, an infested plant, and Fig. 10, showing one unaffected. The difference is further explained in the following pages.

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[7] Am. Journ. Sci., 1841, vol. XLI, pp. 153–58.
[8] Inj. Ins. Mass. Ed., 1841, pp. 421–37.
[9] The Cultivator, vol. 8, p. 82, 1841; Am. Farmer, vol. II, p. 235, 1820.
[10] N. Y. Tribune, Sept. 12, 1877; Third Rep. U. S. Ent. Comm., p. 211.
[11] American Farmer, vol. III, p. 188, Sept., 1821.
[12] The Hessian Fly, Lecture, p. 7.

EFFECT OF LARVÆ ON PLANTS IN THE FALL.

The effect of the larvæ, especially on the young plants, does not appear to be generally understood, and I have myself been able to verify either the figures or descriptions of Fitch and Packard, only in exceptional cases. The swollen bulb just above the roots in Fitch's figures gives but a vague idea of the true appearance, while Packard's figure represents plants which have very evidently sprung from seeds only slightly covered by the soil. Besides, the former figure only represents the condition of the plants long after the larvæ have done their work, and the latter, aside from one shoot being shorter, gives no idea of the appearance of an infested stem, as found in nature, growing in the fields. The yellow color of the foliage — there is usually more brown than yellow about it — appears later, after the larvæ are full-fed, and then it is largely, at least, confined to the younger leaves, the older ones, under whose sheaths the larvæ occur, are killed by the freezing weather of winter. I give a representation of an infested plant fresh from the field, drawn from nature, in Figure 9.

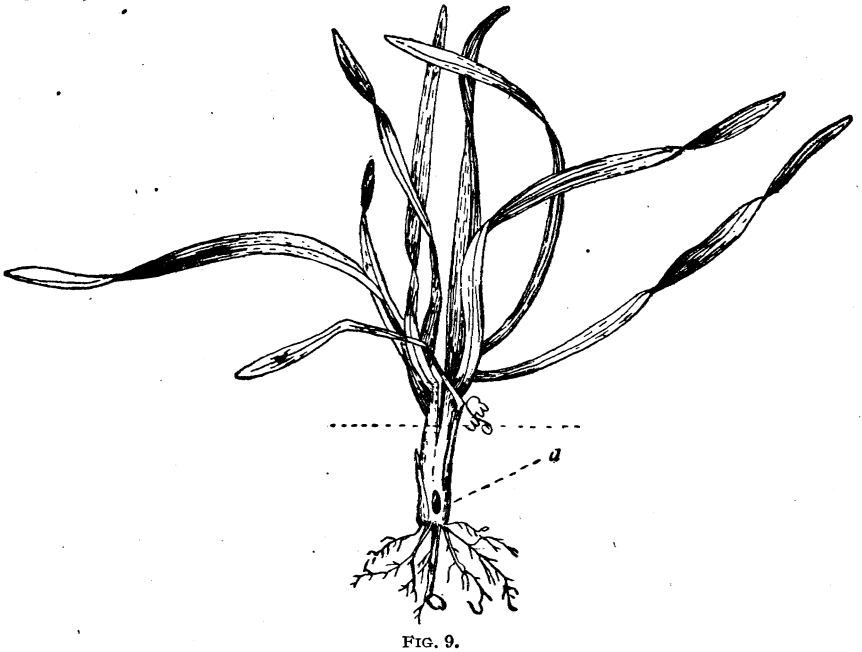

FIG. 9.

The plant had been attacked soon after its appearance above ground and had not tillered. The leaves under these conditions are broader, darker green, more vertical and bunchy. The youngest leaf on a healthy plant as it unfolds and pushes upward is of a tubular form and spindle-shaped, as represented in Fig. 10, showing a healthy plant. In the case of an affected plant, the stem having been destroyed below ground, the

spindle-shaped central leaf is always absent. The difference between a healthy and infested plant is shown by a comparison of figures.[13] If a plant has already tillered, each of the identical laterals, as they are attacked, will begin to take on the form and color above described. It is, therefore, not only possible to detect an infected plant without removing it from the ground, but also to determine the individual tiller infested. Now, while this feature of infested plants is so very clearly marked, at least after the larvæ are one-third grown, and from an economic standpoint of so much importance that it is surprising that it should have been overlooked, yet I can not myself lay claim to the fact by right of discovery, as it was pointed out to me by a farmer in the autumn of 1884.

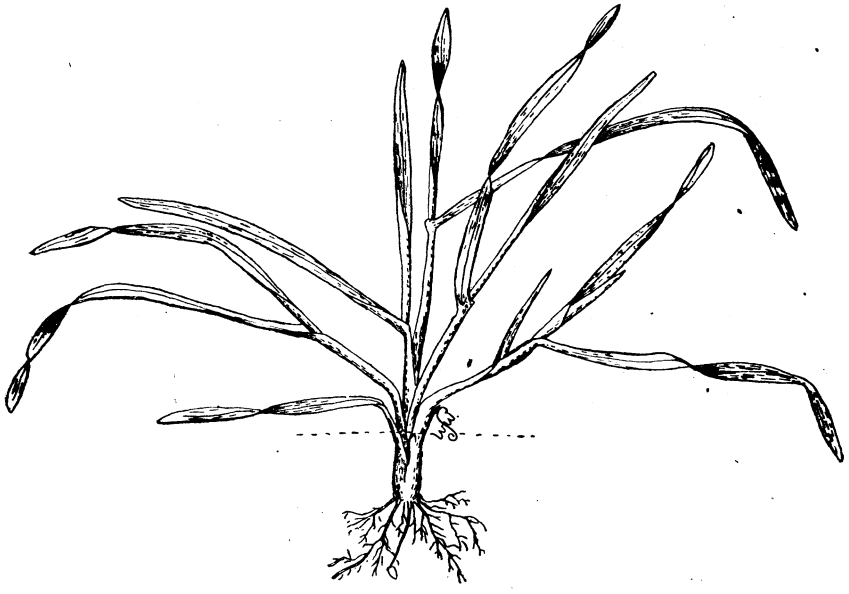

FIG. 10.

If the soil is rich and the plants are attacked before they have tillered, these last will be thrown out from the roots which are not injured. These, if the fall be very favorable, and the winter does not commence too early, will often winter through and produce stem-bearing heads the following harvest. On the other hand, if the autumn be dry, or the

[13] When this matter was published, I supposed I was the first to record and figure this difference between healthy and affected plants. I now find that I was anticipated by about 65 years. *The American Farmer*, vol. II, p. 174, 1820, contains an illustration of both healthy and affected plants, in which this difference is clearly shown by the artist, and while there was no reference to this difference in the text, in the same publication, of August 15, 1823 (vol. V, p. 165), Mr. Thomas Beesley, writing from Cape May, says: "For the information of those that may not know how to find the fly in the fall, they will look for the spears that are the darkest green and stand most upright."

ground be frozen early in the season, the crop will probably prove a failure. This is the reason why some fields will present a much better appearance the following June, and give a much better yield than could have been anticipated from appearances during the fall. The practical value of knowing how to detect the infested plants readily is in that the destruction may be observed and the damage estimated long before the foliage turns brown or yellow, and the fields be plowed up and resown or allowed to remain, as the owner judges best. If resown, it would seem best to replow also. Mr. W. A. Oliphant, of Pike county, southern Indiana, writing me in the fall of 1884, in reply to a circular, stated that of 300 acres he had resown 200 acres after replowing, and 100 acres without plowing. The first yielded him 27½ and the last 11 bushels per acre.

EFFECTS OF LARVÆ ON PLANTS IN SPRING.

The popular notion in regard to the effect of larvæ on the straw is, so far as I know, usually correct. The year 1890, however, was an exception, at least so far as southern and central Indiana is concerned. As far north at least as LaFayette the larvæ of the spring brood were located just above the roots, and the straw did not break at the lower joint, as is usually the case, but either fell or was blown over from the roots, the culm usually being uinjured elsewhere. I observed this to a very limited extent at Oxford, Indiana, in 1881. In fields about La Porte, in the northern part of the State, none of this lower attack of the plant was noticed, the larvæ and later the puparia being invariably found just above some of the lower joints. Mr. James Fletcher, Dominion Entomologist of Canada, reported at the meeting of the Entomological Club of the American Association for the Advancement of Science at Indianapolis, that the wheat about Ottawa, Canada, had that year suffered from the attacks of larvæ of the spring brood in precisely the same manner as I had observed at LaFayette and southward. Quite a percentage of the pupæ in the fields about La Porte were located so high up the stem as to render it probable that they would be carried away with the straw. As yet I have not found a good reason for this difference, but have a vague idea that the killing down of the plants during the preceding March might have had something to do with it, as this was less severe in the northern part of the State.

THE EFFECT OF THE WEATHER ON THE DEVELOPMENT OF THE FALL BROOD.

It is quite probable that some autumns are more favorable for the development of the insect than others, but just what the favorable influences are is not well understood. Mr. Ratliff, at Richmond, Ind., saw an adult emerge from the pupa on October 16; the wheat which it infested appeared above ground on September 4. Between these two dates, Mr.

Ratliff's notes give the following record of minimum temperatures through which the insect must have necessarily passed:

	Min. Temp.
September 23 (frost)	26°
October 6 (light frost)	26°
October 11 (light frost)	34°
October 12 (light frost)	26°
October 14 (heavy frost)	24°
October 15 (frost)	26°
October 16 (light frost)	29°

Rains on September 11, 26, October 10. Total precipitation during September and October 2.50 inches.

At LaFayette, the same year, I found adults ovipositing on November 3, but of the origin of these flies of course nothing was known. The temperature through which these must have passed, supposing the eggs from which they evolved were deposited after September 1, was as follows:

	Min. Temp.
September 23	39°
September 24 (first frost)	29°
October 11	39°
October 12 (frost)	29°
October 14 (frost)	33°
October 15 (frost)	31°
October 16	38°
October 19 (frost)	31°
October 20 (light snow)	37°
October 21	29°
October 22	21°
October 25 (frost)	19°
October 26 (frost)	21°
October 27 (frost)	21°
October 28 (frost)	28°
October 29	33°
October 30 (frost)	19°
October 31	28°
November 1 (frost)	28°
November 2 (frost)	36°
November 3 (frost)	32°

Rains on September 7, 13, 14, 22, 27, 28, 29, 30, October 3, 9, 10, 12, 23. Total rainfall, 4.64 inches.

From this it will be observed that the adult flies may emerge and oviposit under what we supposed to be very adverse circumstances. To what extent the eggs and young larvæ are able to withstand such weather I have no facilities at present for demonstrating. The major portion of the fall brood of flies, however, emerge during a more favorable period, and for meteorological aid against these we can only look to the dry, hot weather of July and August, though to the south a portion of September

might be included. But the straggling individuals, which, as I have proved, may originate from stubble, volunteer, or even early sown grain, and which I myself can find no satisfactory reason for not considering either the retarded or accelerated individuals of either one or the other of both broods, have it in their power to reproduce a considerable progeny, which, though of themselves not a serious menace to the crop, yet, added to those of the remainder of the forthcoming brood, greatly increase the probabilities of serious damage. For these a long mild autumn, extending into December, would appear to be exceedingly favorable as it would enable their progeny to enter winter in a comparatively hardy state, and probably produce late appearing larvæ the following year, simultaneously with or but little in advance of the progeny of the earlier appearing adults of spring. In other words, the one winters as advanced puparia or unemerged adults, the other as advanced larvæ or newly formed puparia. It thus appears that while the autumn usually has little effect on the major portion of the fall brood, a mild October and November may emphasize the destructiveness of the pest. So far as observed by me, a damp spring, even though a cold one, is also favorable to the development of the insect, while dry, hot summers are as unfavorable, and cause serious mortality to the earlier stages of the fall brood of adults.

PREVENTIVE MEASURES.

These may be noticed as follows: Sowing at the proper time; burning the stubble; rotation of crops; sowing long, narrow plats in late summer as baits; applying quick-acting fertilizers to seriously infested fields in the fall in order to encourage attacked plants to throw up fresh tillers, and to increase the vigor of these that they may make sufficient growth to withstand the winter.

None of the measures are original with me, and in fact the most of them are as old as the history of the species itself. There is certainly much to be gained by the farmer in timing his sowing so as to avoid the larger part of the fall injury, and if all farmers of a neighborhood would sow about the same time even a serious outbreak would be so diffused as to lessen its injury.

Burning the stubble after harvest, recommended as long ago as 1792, when it is practical to do so, is usually recommended by the majority of writers. The plan is criticised by some authors on the plea that the parasites are also destroyed, which, if allowed to continue, would themselves overcome the fly. This idea has always appeared to me to be both theoretically and practically wrong. If only the normal number of wheat plants allowed by nature to spring up under a perfectly natural environment were produced, then the theory would be correct, because nature would then be working out her plans from the beginning. As the facts exist hundreds of thousands of plants are produced where nature intended

but one. Her domain is invaded and her law defied at the beginning. The Hessian fly is itself a parasite, the wheat plant being its host, and what we term its parasites are practically only secondaries. In the Hessia fiy, nature has an efficient servant in controlling the wheat plant, and the parasites of the former seem to be on guard to see that the duty is not overdone. Now we outrage nature and expect that she will uphold us by destroying these servants and permitting the indignity to go on. With this state of affairs the American farmer has found that the Hessian fly will be overcome by its parasites only temporarily, and then at the expense of a large per cent. of at least one crop. By burning the stubble we destroy all of the pest and also numerous other enemies which are to be found in the fields at the time. Some seasons, however, many of the flaxseeds were so situated that it is doubtful if enough heat would reach them to destroy all of them.

In a rotation of crop the adults are obliged to travel about in search of the fields, and there is a greater chance of their being destroyed while thus engaged. This, however, has its exceptions, as we observed at New Castle, about thirty miles northwest of Richmond, Ind., on November 17, 1888. The whole field had been sown in standing corn, a portion of it about the 5th of September and the remainder considerably later. The early sown portion had been seriously attacked and at least 85 per cent. destroyed; the later sown portion was only slightly injured, as was late sown wheat generally in the community. At the Indiana Experiment Station the plan of rotation is as follows: Corn one year, followed by oats one year, wheat one year, clover and grass two years. The wheat fields are then never seriously affected by the ravages of the Hessian fly.

Sowing narrow strips across the fields, early in the fall, as decoys, was long ago strongly advocated by Dr. Fitch, but the advice has been, so far as I have observed, totally ignored by the farmer. While it is hardly possible to thus entrap the major part of the fall brood of larvæ, it is certainly possible to entice to these plats the stragglers and interlopers, which we have shown to be capable of considerable injury. In this way the farmer can, in a measure, continue the influences of summer and winter in sharply separating and defining the two broods. In other words, while he can not eradicate the pest in this way, he can weaken its power to commit serious injury. It is very doubtful if the volunteer wheat springing up after the wheat land has been plowed, can be used as decoys, and if allowed to stand until the date of sowing the fields, these volunteer plants should, by all means, be plowed under as deeply as practicable. Simply killing the plants will not do, as has been illustrated by the experience of Mr. Oliphant, previously cited, and by the observations of Professor Forbes, of Illinois.[14] If volunteer wheat is allowed to stand at all, it should not be over a fortnight. The proper time for sowing these decoys will probably vary with the latitude. For northern Ohio they should

[14] Bulletin 3, State Ent. Ill., p. 48, 1887.

be sown during the latter part of August, and in the southern part of the State not later than the first week in September. To the north and south of this State I have, as previously stated, no definite information as to the date of appearance of the fall brood of flies, and hence cannot undertake to settle the date of sowing. These decoys should not be permitted to stand over four weeks at the farthest, and should be plowed very soon after the crop is sown, turning the infested plants under and thoroughly covering them. Simple cultivation whereby the plants are only killed, would probably only destroy a portion of the insects, the full-grown larvæ very likely going through the remainder of their transformations.

The application of fertilizers is, I believe, in Ohio as well as Indiana confined to the poorer soils, and there more for its general effect on the crops than as against the effects of insects. The idea in late sowing is to retard the plants so that they do not appear until after the greater part of the fall brood of flies have appeared and died, than to overcome the effect of this delay by aiding the plants to make the greatest possible growth before winter closes in, which will the better enable them to withstand its rigors. In this direction, it would seem that the application of proper commercial fertilizers would pay by the effect upon the growing plants, even though the land itself was not in actual want of such treatment. The application to a field which has previously been seriously damaged, with a view of encouraging the throwing out of fresh tillers, is for practically the same purpose; and if there is a tendency to throw out the later shoots freely, if not too late in the season, many may be enabled to secure sufficient vigor to sustain them until spring. Whether it would be more profitable to plow and resow than to try to secure a crop from the infested field by the aid of fertilizers is, of course, a question which each farmer must decide for himself in accordance with the time of year and extent of injury already done.

These measures are all of them practical and entail little if any unusual expense. In fact, good farming presupposes that the most of them will be carried out as among the essential elements of the business. Where clover is to follow wheat it of course precludes the burning of stubble or the destruction of volunteer plants, but it necessitates the rotation of crop, and decoys can be sown and the seeding delayed. It is hardly possible for a farmer to become so situated that he can not carry out some of these measures, and if this were done generally and every year, the Hessian fly would, in all probability, become of so little importance that it would cease to enter seriously into the problem of successful wheat growing.

There is another measure, which, if carried out, would tend to reduce the severity of the fall attack, in many cases. But the "perversity of human nature," will hardly permit of putting it into practice. I refer to a unanimity in time of sowing, whatever the date may be. If this were done the plants in all fields would appear above ground at about the same

time, and serve to scatter the fly over so large an area, that, though numerous, they would work less injury than if confined to a few fields. If neighborohoods or counties would unite in doing this, much of the present loss by this pest would be saved. As it is, somebody is sure to sow at the wrong time, and thus the species is carried over in great numbers, to work injury the following year.

After thirteen years of study of the Hessian fly (*Cecidomyia destructor*), I am satisfied that four-fifths of its injuries may be prevented by a better system of agriculture. For years I have seen wheat grown on one side of a division fence without the loss of a bushel by attack of this pest, while on the other side the crop was almost invariably more or less injured. No effect of climate, meteorological conditions, or natural enemies could have brought about such a contrast of results. The whole secret was in the management of the soil and the seeding. In fact, the question of success in evading the pest, in the one case, did not appear to be an entomological one at all; and I am fully convinced that the Hessian fly problem, so far as it relates to agriculture, throughout that portion of the country lying between the Allegheny Mountains and the Mississippi River, and between the Ohio River and the Great Lakes, may be considered practically solved.

In conclusion, permit me to make some suggestions as to seeding, even though it may appear beyond the pale of an entomologist. In the first place get good seed. You can not grow healthy wheat plants, that will resist the attack of the fly or any other insect, by sowing shrunken, unhealthy kernels. If you wish fifty bushels of seed take them from out of a hundred, and take only the largest and best grain. Sowing late does not mean putting off the preparation of the ground until the last day, and then hurrying in the crop. Plow early and do not bestow work grudgingly on your field. Get a compact, smooth, well pulverized seed bed at any cost, so that the seed will be evenly covered and not one portion covered six inches deep and other portions one inch deep. Nothing will pay better than this. With every thing in readiness, wait patiently until the fly has emerged, and largely at least, disappeared, then sow your grain as carefully and as well as you would if you were planting your last dollar. In ordinary seasons the sire (seed), with the assistance of mother earth, will give you a growth of sturdy, hardy, thrifty plants that will have dodged the fly, escaped the rust and will go into winter in better condition than if sown early and in a slip-shod manner. In the spring this grain will meet even a quite severe attack of the fly and the effect will partake more of that of the pruning knife than the sickle. Rich soil will of course have the advantage, but if not rich do not abuse it because it is poor, as that is all the more reason for good culture. The army worm, which loves a rank growth, and, possibly, the wheat midge excepted, I know of no wheat destroying insect that will not be placed at a disadvantage by this treatment.

REMEDIES.

After the fly has gained possession of a field, I know of no application that can be made which will destroy it. Doubtless pasturing the field, if early sown, will often result in reducing the numbers of the pest, besides giving to the ground that compact, pulverized nature, which it should have had at the first. No doubt many larvæ and "flaxseeds" by

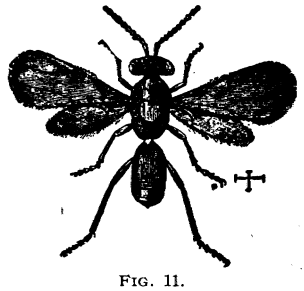

FIG. 11.

this means would be crushed, but very few would enter into the food of the animals grazing thereon, unless the plants were pulled up both stem and roots. In pasturing sheep are preferable to large animals.

NATURAL ENEMIES OF THE HESSIAN FLY.

For America the following species have been recorded:

CHALCIDIDÆ.

Merisus destructor Say. (Fig. 11.)
Bæotomus subapterus Riley.
Pteromalus pallipes Forbes.
Eupelmus alynii French.
Entedon epigonus Walk. (Artificially introduced.)

PROCTOTRYPIDÆ.

Polygnotus hiemalis Forbes.
Platygaster herrickii Packard.

As secondary parasites we may record *Tetrastichus productus* Riley, and *Tetrastichus carinatus* Forbes.

In Russia Dr. Lindemann records the following:

CHALCIDIDÆ.

Merisus intermedius Lindm.
Entedon epigonus Walk. (Semiotellus nigripes Lindm.)
Eupelmus karschii Lindm.
Euryscapus saltator Lindm. (Reared also from galls of *Isosoma hordei*.)
Tetrastichus rileyi Lindm. (Secondary parasite of *Merisus*.)

PROCTOTRYPIDÆ.

Polygnotus minutus Lindm.

In England, Miss Eleanor A. Ormerod and Mr. Fred. Enock have obtained the following parasites:

CHALCIDIDÆ.

Merisus destructor Say.
Bæotomus subapterus Riley
Merisus intermedius Lindm
Entedon epigonus Walk.
Eupelmus karschii Lindm.
Euryscapus saltator Lindm.
Tetrastichus rileyi Lindm.
Tetrastichus. (Two species.)

PROCTOTRYPIDÆ.

Polygnotus minutus Lindm.
Platygaster herrickii Packard.

Dr. Marchal records from *Cecidomyia destructor* the following as being obtained from Vendée, France:

CHALCIDIDÆ.

Merisus destructor Say.
Holcæus cecidomyiæ Ashmead.
Bæotomus rufomaculatus Walk.
Eupelemus atropurpureus Dalm.

PROCTOTRYPIDÆ.

Polygnotus minutus Lindm.
Polygnotus zosini Walk.
Trichasis remulus Walk.

The above lists are taken from a recent bulletin on "The Hessian Fly in the United States," by Prof. Herbert Osborn, this being Bulletin 16, New Series, of the U. S. Department of Agriculture, Division of Entomology.

Referring to these natural enemies Prof. Osborn further states that their importance is probably difficult to over-estimate and that there is abundant reason for a careful consideration of the various species of insects known as attacking Hessian fly, owing to the fact that probably fully nine-tenths of these insects are destroyed by those parasites. I need hardly say that my own studies fully substantiate these statements, and I am satisfied that but for its natural enemies the Hessian fly would render it impossible to grow wheat, successfully, in many sections of the United States. I have included in this paper the lists of such natural enemies as have been reared not only in America but in Russia, England and France. As will be seen at a glance, there is a great similarity between these parasitic enemies in the four countries indicated. I might call attention to the fact that it is very often a curious experience with farmers that the fly will be excessively abundant during one season, while the next it will seem to have almost entirely disappeared. Careful studies

of the fly, at such times, reveal the fact that so very few of them escape the attacks of their natural enemies that the insect is in reality reduced in numbers, almost to the point of extermination; but, at this point, a reduction in the number of natural enemies must necessarily take place, on account of the lack of flies for their support, so that both host and parasite come to the bottom, in point of numbers, and the fly, the following year, being relieved from its enemies, which will die out for want of food, again starts in its progress upward in point of numbers, to be followed later by its enemies. These gradually work upward, until there comes a time when there is an excessive abundance of flies, and these afford ample food for the parasites until the two are again forced to the bottom to start again anew. This has given rise to the oft repeated explanation by the unscientific, that it matters little what insect appears it will be only a question of time when something will occur to destroy it. However, the fact that the insect pest must get to be very abundant, and work serious injury, before its natural enemies can increase sufficiently to destroy it is entirely lost sight of. What is really needed here is man's interference, to prevent the destructive insect from becoming abundant enough to destroy his crops. If we get at this in the right way, we shall be able to keep the Hessian fly so reduced in numbers that its natural enemies will take care of it. But these natural enemies are susceptible to weather conditions, and frequently parasites cannot be relied upon to, always, hold the destructive species in check; but if farmers could only understand the habits of the Hessian fly and its enemies, they would be far better able to so manipulate their crops, in times of plowing and sowing, that the fly would be unable to breed in such overwhelming numbers, and the farmer's insect friends would thus be enabled to hold the depredator in check.

SUMMARY.

The Hessian fly is a small, dusky-colored, two-winged insect, about one-eighth of an inch long. It appears during spring and fall, the former period extending, in Ohio, throughout the month of May and probably the first half of June, and the latter, or fall brood, extending through the last days of August and much of September in the northern part of the State, and the last of September and the first week or ten days in October, in the extreme southern portion of the State. The eggs are deposited in both spring and fall on the upper side of the leaves, and the young, as soon as they hatch, make their way down the plant behind the sheath of the leaves. In the spring, they go down to the first or second joint above the roots, but in the fall, when the plants are much smaller, they usually go down to a point just above the roots, indicated in Figue 9 by letter *a*. The effect on the wheat, in the fall, is to prevent the plant from sending up shoots that would bear heads the follow-

ing year, and to reduce the growth to a mere bunch of rank growing leaves, that kill out during the winter. In the spring, the maggots, or young, go down to the first or second joint above the roots, and there become imbedded in the straw, thus weakening it, and when the grain comes to head, the straw thus weakened will topple over and break down, thus giving rise to what is known as "straw fallen" grain. The insect passes the winter, largely, in the flaxseed stage about the plants, just above the roots. It passes the summer, largely at least, in the stubbles that are left in the fields at harvest. Thus the adults breed in spring and fall at dates varying with the latitude. They live but a few days and die almost immediately after depositing their eggs. The preventive measures are late sowing, rotation of crops and burning of stubble, where this can be done. The remedies consist in the use of quick-acting fertilizers, in the fall, or pasturing early sown fields, preferably with sheep. There is no known remedy against the spring brood of flies.

PUBLICATIONS

OF THE

OHIO AGRICULTURAL EXPERIMENT STATION.

A complete list of previous publications of this Station may be found in Bulletin 95. Following are the titles of subsequent bulletins:

No. 96. The Army Worm and other insects; Wheat and Grass Sawflies; the Corn or Boll Worm; the Painted Hickory Borer; the Raspberry Cane Borer; the Peach Scale.
No. 97. Diseases of wheat and oats.
No. 98. Small fruits; cultural notes and comparison of varieties.
No. 99. Sugar beet investigations in 1898.
No. 100. A comparison of factory-mixed and home-mixed fertilizers.
No. 101. Experiments with oats.
No. 102. Soil and seed treatment and spray calendar for insect pests and plant diseases.
No. 103. The San José Scale in Ohio.
No. 104. Further studies upon spraying peach trees and upon diseases of the peach.
No. 105. Further studies of cucumber, melon and tomato diseases.
No. 106. The chinch bug; experiments with insecticides.
No. 107. The Hessian fly.

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